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**THE EFFECTS OF SAFETY INFORMATION ON
AERONAUTICAL DECISION MAKING**

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ABSTRACT

The importance of aeronautical decision making (ADM) has been considered one of the most critical issues of flight education for future professional pilots. Researchers have suggested that a safety information system based on information from incidents and near misses is an important tool to improve the intelligence and readiness of pilots. This paper describes a study that examines the effect of safety information on aeronautical decision making for students in a collegiate flight program. Data was collected from study participants who were exposed to periodic information about local aircraft malfunctions. Participants were then evaluated using a flight simulator profile and a pen and pencil test of situational judgment. Findings suggest that regular access to the described safety information program significantly improves decision making of student pilots.

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INTRODUCTION

Sound pilot decision making is essential to the safe completion of every flight. O'Hare (2003) indicates that "It is difficult to think of any single topic that is more central to the question of effective human performance in aviation than that of decision making" (p. 230). The term aeronautical decision making (ADM) has been used to describe and assess pilot judgment within many aviation circles (Jensen, 1997). Paradoxically, aeronautical decision making, so crucial to the safety of flight, often receives scant emphasis in pilot training. Richard Jensen, the General Chair of the Ninth International Symposium on Aviation Psychology, commented, "Unfortunately, most student pilots do not receive structured decision making or judgment training either in their initial or later flying experience...[and]...How can we expect them to reach above the level of competence if we do not teach judgment?" (Jensen, 1997, p. iv). Jensen suggests that training in aeronautical decision making/judgment can take the form of reading case studies about accidents and incidents as well as studying the experiences of other pilots in abnormal situations.

Eiff (1999) suggests that the state of intelligent and respectful wariness can foster a heightened state of vigilance for error potentials and dedication to performing safe acts. In addition, Reason (1997) notes that:

In the absence of bad outcomes, the best way—perhaps the only way—to sustain a state of intelligent and respectful wariness is to gather the right kinds of data. This means creating a safety information system that collects, analyzes and disseminates information from incidents and near misses as well as from regular proactive checks on the system's vital signs. (p. 195)

Many safety information systems in aviation have been developed around the world, including the Aviation Safety Reporting System (ASRS) developed by the National Aeronautics and Space Administration (NASA), the Confidential Human Factors Incident Reporting Programme (CHIRP) used in the United Kingdom, and the British Airways Safety Information System (BASIS). Three years ago, Purdue University researchers created a safety information system entitled the Aircraft Discrepancy Analysis Metrics (ADAM). Dillman, Lee, and Petrin (2003) have reported on detailed features of ADAM and its utilization. ADAM was originally designed to gather, track, and analyze aircraft discrepancies as a tool for aircraft safety management. It has been used to compile five years of information on mechanical discrepancies for all Purdue aircraft. The description of every aircraft discrepancy written in each logbook has been analyzed and

categorized into a unified metric format. However, most Purdue aviation students are unaware of ADAM because its main application has been at the resource management level.

The content and structure of initial flight education, as in other fields of education, are extremely important. Jensen (1997) feels that “initial training can have an effect on certain aspects of flying that may carry throughout one’s career” (p. v). Clearly, initial training in a collegiate flight program is one of the most defining stages for future professional pilots. It is imperative that students acquire sound decision making strategies from the very beginning as this skill forms the basis for an approach to safety decisions throughout their entire professional career. Since most flight education employs little structured judgment training, a safety information system would appear to be a valuable instrument for enhancing desired student aeronautical decision making.

The purpose of this study was to assess whether a safety information system could effectively improve aeronautical decision making for students in a collegiate flight program. Three theories support the potential benefits of safety information to flight students’ decision making: the Detailed Judgment Model (Jensen, Adrion, Maresh, & Weinert, 1987), Naturalistic Decision Making Theory (Lipshitz, 1993; Orasanu & Connolly, 1993; Thargard, 1988), and the Learning Framework (Gredler, 2001).

Jensen, Adrion, Maresh, and Weinert (1987) use their Detailed Judgment Model to explain that aeronautical decisions are made with rational and motivational judgments. A safety information system is thought to be beneficial for rational judgment. While motivational judgment deals with personal motivation to execute a suitable course of action, rational judgment follows five sequentially connected steps: problem vigilance, problem recognition, problem diagnosis, alternative identification, and risk analysis. For these steps of rational judgment, a good source of information will help pilot vigilance. Pilots generally use the simplest or most economical interpretation of a stimulus to arrive at the interpretation most likely to match the source of stimulation during problem recognition. Problem diagnosis requires an understanding of prior probabilities for certain events, and comes into significant play when there may be a mechanical problem with the aircraft. The stage of rational judgment where alternatives are identified requires creativity and knowledge of the aircraft. Risk analysis requires computational approximation skills and knowledge of the relative safety in different courses of action (Jensen, 1995).

Naturalistic Decision Making Theory advocates support the beneficial effect of a safety information system. Lipshitz (1993) says that experts in naturalistic decision making tend to generate a single course of action as the best choice. Based on the classification of the problem, decision makers provide a single highly likely option and evaluate its appropriateness to the

current conditions. Orasanu and Connolly (1993) also say that decision makers use their knowledge to organize the problem, to interpret the situation, and to define what information is needed to arrive at a solution. This process allows the decision maker to make a speedy assessment, search, selection, and interpretation of relevant information.

Finally, the Learning Framework reported by Gredler (2001) depicts the potentially beneficial effect of a safety information system to flight students. The learning framework consists of the learner's prior knowledge and organization of the information (encoding) to be learned. The learner's prior knowledge serves to identify incoming information and also influences the inferences made by the learner about new information. Encoding is the process that prepares selected information for storage in long-term memory and later recall. Encoding requires the construction of meaningful links between the new concepts or ideas and the learner's prior knowledge. The higher cognitive functions are characterized by conscious awareness of the encoding process and permit the individual to make use of logical relationships and generalizations (Gredler, 2001).

RESEARCH QUESTIONS

This study considered the hypothesis that a safety information system such as ADAM would have a beneficial effect on student pilots' aeronautical decision making in critical flight safety situations. The following research questions were developed to direct the study.

1. Is the *recognition time* for abnormal aircraft conditions shorter for flight students exposed to periodic review of ADAM than for non-exposed students?
2. Is the *response time* for abnormal aircraft conditions shorter for flight students exposed to periodic review of ADAM than for non-exposed students?
3. Do the flight students who periodically review ADAM follow more appropriate procedures to resolve an abnormal aircraft condition than those who do not?

METHODOLOGY

Participants

Volunteers were recruited from a population of students who were in their second to fourth semesters of a baccalaureate degree program, had received their private pilot certificate, and were training for a commercial pilot certificate. Study participants were randomly selected from the volunteer pool and randomly assigned to equally sized experiment and control groups. Based on a statistical power analysis, forty volunteers were initially assigned to the study. However, six individuals later discontinued

their participation and were dropped from the study. As a result, study findings are based on data collected from 34 participants (17 in each group).

Research Design

The study treatment consisted of measured access to current ADAM information. This access was through the university's online teaching structure using WebCT Vista. Each flight student in the experimental group was provided WebCT access to the ADAM database throughout the duration of the study. These students were directed to review ADAM prior to each flight and specifically focus on the discrepancy history of the aircraft that they would be flying. Furthermore, periodic reminders and announcements were posted online that directed students to be wary and focus on particular systems failures. This treatment was provided to the experiment group eight times over a five-week period and included information on aircraft system malfunctions. In addition, the control and experiment groups both completed a pre- and post-treatment pencil and paper test of decision making skills and a short simulator profile flight. The ADAM treatment was the independent variable for this study and the dependent variable was flight student judgment during critical flight safety situations, measured in terms of recognition time, response time, and appropriate actions. The ADAM treatment was postulated to positively influence flight student decision making.

Instrumentation

To answer the research questions in this study, two types of instruments were used, the Situational Judgment Test (SJT) and a Frasca 141 profile flight. The SJT is a paper and pencil type instrument developed by the Federal Aviation Administration (FAA) to assess general aviation pilots' decision making skills. Hunter (2003) advises, "the SJT has potential for use in the assessment of judgment or aeronautical decision making by general aviation (GA) pilots, and might be useful in the evaluation of training" (p. 373). The SJT is used to evaluate differences between solutions recommended by an FAA-designated panel of subject matter experts and judgment/decisions made by general aviation pilots (Hunter, 2003).

A Frasca 141 flight-training device (FTD) was used to measure study participants' decision processes during abnormal flight conditions. A detailed FTD test plan was developed under the supervision and guidance of a local panel of flight experts. This five-member panel was composed of FAA-designated flight examiners, flight instructors, and professional aviation maintenance technicians. The panel's advice concerning the technical and mechanical issues of aircraft and simulator operation were pivotal in the planning of the test events. Activity in the FTD included a preflight briefing and a flight profile with periodic malfunction trigger

events. Participant activity in response to the malfunctions was recorded on an assessment form.

Three variables were measured during the FTD flight: recognition time, response time, and appropriateness of response to the trigger events. Recognition time was measured from the introduction of a simulated aircraft system malfunction (trigger event) until the participant recognized the situation. The indications of recognition were either the participant's verbal expression or physical action of recognition, such as pointing out the appropriate aircraft performance indicator or initiation of corrective action (e.g., turning off an alternator switch for alternator failure). Maximum waiting time until a participant recognized the event was planned as 300 seconds (five minutes). If a participant did not recognize the event within the time line, the participant's recognition time was recorded as 300 seconds.

Response time was measured from recognition of a simulated abnormal aircraft condition (trigger event) until the participant completed the corrective actions. If a participant did not initiate any corrective action until after 300 seconds (five minutes), the response time was reported as 300 seconds.

Appropriateness of response to an abnormal aircraft condition was measured by analyzing the participant's sequence of corrective actions. These corrective actions were compared with recommended procedures in the Piper Warrior III pilot's operating handbook and the FAA-approved airplane flight manual (Piper Warrior, 1995). In measuring corrective actions, two considerations were applied: did the corrective actions include all steps from the recommended procedure, and were the corrective actions completed in the recommended sequence. These measurements were recorded with numeric scores on an assessment form.

Trigger events for the FTD profile were selected after consideration of guidelines provided by the flight expert panel. Only trigger events that could be initiated from the simulator instructor's control console were used. Profile standardization could only be assured if the timing for a trigger event, the control of the trigger event, aircraft position in the profile, and flight altitude were controlled in a consistent manner from the control console. In addition, trigger events should produce an immediate instrument or warning light indication when initiated. Recognition time for each trigger event was based on a video record that captured the elapsed time from when a trigger event was initiated until the participant recognized the event, as evidenced by an auditory cue or observable action. Therefore, immediate instrument or warning light indication was essential in order to have a starting point for measuring those times. Finally, each trigger event should have only one appropriate corrective action as specified by the Piper Warrior III pilot's operating handbook and the FAA-approved airplane flight manual (1995). Corrective actions to each trigger event were measured by counting

deviations from the recommended corrective action, missed steps in the procedure, and actions not completed in the recommended sequence by a participant. Using these guidelines, four trigger events were eventually selected for use during the FTD profile: alternator failure, high oil pressure, high load meter, and vacuum pump system failure.

A flight profile was developed to set uniform flight parameters for each participant. The flight profile was divided into four legs and each leg included one trigger event. During the flight profile, participants were asked to make periodic heading or altitude changes to make the flying condition more realistic and reduce the anticipation of trigger events. To minimize possible threats to internal validity caused by participant interaction with the FTD, the flight profile was only completed posttest (after the treatment). The SJT was completed pre- and posttest. Measurements for each test are summarized in Table 1.

Table 1. Study measurements

Instrument	Pretest		Posttest		Measurement
	Experiment Group	Control Group	Experiment Group	Control Group	
Frasca 141 FTD	N/A	N/A	Yes	Yes	Recognition Time
Frasca 141 FTD	N/A	N/A	Yes	Yes	Response Time
Frasca 141 FTD	N/A	N/A	Yes	Yes	Appropriateness of Response
SJT	Yes	Yes	Yes	Yes	Adherence to Recommended Solution

Since the Frasca 141 FTD cockpit display has no circuit breakers, unlike a real aircraft, a simulated circuit breaker panel was made and affixed to the instrument panel of the simulator to facilitate completion of required corrective actions. In addition, the front monitor screen of the simulator was set to represent Visual Meteorological Conditions (VMC) for participant reference. All flight performance was videotaped to capture data for later analysis. Data acquired with the SJT and Frasca 141 FTD was reviewed and analyzed using the *SAS System for Windows* (SAS Institute, 2004).

RESULTS

The SJT instrument is structured in a multiple-choice format with four alternative choices to each question. The answer choices for each SJT question were ranked from most correct to least correct by FAA-designated subject matter experts. Participants who took the SJT were asked to select

their best choice among the four possible answers to each question. Adherence of participant's decision to the recommended solution was measured by comparing how close the participant's choice was to the most correct answer recommended by the expert panel. An Analysis of Covariance (ANCOVA) analysis with the posttest SJT as the response variable and the pretest SJT as the covariate was applied to the data. The results of this test indicated a statistically significant difference between the control group and the experimental group for posttest SJT scores ($F = 36.40$, $p < 0.0001$), which suggests the positive effect of an ADAM treatment.

The difference between posttest and pretest SJT scores within the experimental group was analyzed with a regression model. This analysis examined the level of procedural accuracy before and after treatment. The regression analysis indicated that the posttest SJT result of the experimental group was significantly different from their pretest SJT result ($t = 4.71$, $p = 0.0003$). Again, this suggests the positive effect of an ADAM treatment.

Appropriateness of response to an abnormal aircraft condition was measured by analyzing the participant's corrective action to resolve the abnormal condition during the Frasca 141 simulator flight test. The participant's corrective actions were compared with the recommended procedures in the Piper Warrior pilot's operating handbook and the FAA-approved airplane flight manual (1995), and were recorded with numeric scores on a corrective action assessment form. A two-way Analysis of Variance (ANOVA) model with group and experience level as the main factors was used to analyze the difference of corrective action scores. The analysis indicated that the corrective action scores of the experiment and control groups were significantly different ($F = 25.63$, $p < .0001$).

Recognition time for this study was measured from initiation of a trigger event until participant recognition of the event. If a participant did not recognize a trigger event after five minutes (300 seconds), their recognition time was reported as 300 seconds. Recognition times from this study were not normally distributed. Since non-normality violates one of the assumptions for parametric statistical models, ANOVA or regression models could not be considered appropriate for the analysis of recognition times. In this situation, a non-parametric statistical test can be used. One of the most frequently used non-parametric statistical tests is the Kruskal-Wallis Test (Hollander & Wolfe, 1999), and the results for this study are reported in Table 2.

Table 2. Kruskal-Wallis test results for recognition time analysis between groups

Trigger Event	DF	Chi-Square	Pr > Chi-Square
1	1	2.5546	0.1100
2	1	9.5237	0.0020*
3	1	2.0334	0.1539
4	1	4.4361	0.0352*
All	1	14.4857	0.0001*

Note. $\alpha = .05$

Results from the Kruskal-Wallis Tests suggest that recognition times for trigger events 1 and 3 were not significantly different between the experimental and control groups. However, the recognition times for trigger events 2 and 4 were significantly different. Finally, the overall recognition time, which was the summed recognition times of trigger events 1, 2, 3, and 4, was significantly different between the experimental and control groups. These results suggest that flight students exposed to periodic review of ADAM had shorter recognition times for abnormal aircraft conditions than non-exposed students.

Response time for this study was measured from participant recognition of a simulated abnormal aircraft condition (trigger event) until the participant finished the corrective actions. If a participant made no corrective action after five minutes had elapsed (300 seconds), the response time was reported as 300 seconds. If a participant made corrective actions but none of the steps were correct, the response time was also reported as 300 seconds. Five participants (one in the experimental group and four in the control group) made corrective actions to trigger event 3, but none of their actions were correct. If a participant took corrective actions but the actions had a missed step, the ending point of the response time was recorded when the last correct action was made. Nine participants (four in the experiment group and five in the control group) made corrective actions with a missed action step in response to trigger event 1. Five participants (four in the experimental group and one in the control group) made corrective actions with a missed action step in response to trigger event 3. The response time data were found not normally distributed, similar to those seen in the recognition time data. Thus, the same methods used in recognition time analyses, the Kruskal-Wallis Tests, were implemented in response time analyses as reported in Table 3.

Table 3. Kruskal-Wallis test results for response time analysis between groups

Trigger Event	DF	Chi-Square	Pr > Chi-Square
1	1	6.1305	0.0133*
2	1	11.7060	0.0006*
3	1	17.2231	<. 0001*
4	1	1.7178	0.1900
All	1	22.1079	<. 0001*

Note. $\alpha = .05$

The Kruskal-Wallis Test results suggest that response times to trigger events 1, 2, and 3 were significantly different between the experimental and control groups. However, the response time to trigger event 4 was not significantly different. Finally, the overall response time, which is the summed response time to trigger events 1, 2, 3, and 4, was significantly different between the experimental and control groups. These results suggest that the flight students exposed to periodic review of ADAM information completed corrective actions to abnormal aircraft conditions in less time than did non-exposed students. Study findings suggest the following answers to the research questions:

1. Flight students exposed to periodic review of ADAM had shorter recognition times to the trigger events of high oil pressure and vacuum pump system failure than non-exposed students but not to the trigger events of alternator failure and high electrical load. The overall recognition time during abnormal aircraft conditions for flight students exposed to periodic review of ADAM was shorter than the overall recognition time of non-exposed students.
2. Flight students exposed to periodic review of ADAM had shorter response times to the trigger events of alternator failure, high oil pressure, and high electrical load than non-exposed students but not to vacuum pump system failure. The overall response time during abnormal aircraft conditions for flight students exposed to periodic review of ADAM was shorter than the overall response time of non-exposed students.
3. Flight students who periodically review ADAM took corrective action closer to the recommended solutions than those who did not.

DISCUSSION

Jensen (1995) says that people learn to expect certain things to happen from their awareness of predictable elements developed during situational experiences. Barber (1999) mentions situation awareness as anticipating and

considering future situations by monitoring, assessing, and evaluating the current situation. Barber also suggests that situation awareness is essential for the initial stages of problem detection, with information gathering and summarization providing the necessary tools for understanding a more complex situation that may not be straightforward or which may not have been previously experienced. The outcomes from this study support Barber's work. Study participants who periodically reviewed safety information demonstrated enhanced situational awareness and recognized abnormal aircraft conditions sooner than the students who did not. Also, the corrective actions made by flight students who periodically reviewed this safety information were more appropriate than those made by the students who did not. Finally, the SJT results indicated that flight students who periodically reviewed safety information made more appropriate decisions to abnormal flight conditions that they had not previously experienced (many of the scenarios described in SJT were not cases that the study participants would normally encounter in a collegiate flight environment).

Hart (1988) notes that recognition and interpretation of incoming sensory information requires transformation based on expectations, information processing, previous experience, and knowledge of the current situation. In addition, Boff, Kaufman, and Thomas (1986) suggest that perception is the process by which particular relationships among potentially separate stimulus elements are determined and in turn guide the interpretation of those elements. The findings of this study indicate that flight students who periodically reviewed safety information recognized abnormal aircraft conditions in shorter time than the students who did not. Also, the corrective actions for abnormal aircraft conditions, made by the flight students who periodically reviewed the safety information, were more appropriate than the corrective actions made by the students who did not. These results suggest that regular access to safety information enhances flight students' recognition of abnormal aircraft conditions.

Orasanu and Connolly (1993), advocates of naturalistic decision making, say that decision makers use their knowledge to organize a problem, interpret the situation, and define what information is needed to formulate a solution. This process helps the decision maker complete a speedy assessment by searching, selecting, and interpreting relevant information. One of the findings of this study (recognition time) is that flight students who periodically review safety information make faster assessments of abnormal aircraft conditions than those who do not. The study findings also suggest that flight students who periodically review safety information make a more accurate interpretation of relevant information and are more likely to select correct actions.

Ritchie (1988) reports that, depending upon the nature of the display and the pilot's ability to use it, the pilot may be able to process visually provided

information at prodigious rates. One of the study finding areas, recognition time, supports this conclusion. The first trigger event of alternator failure during the Frasca 141 simulator flight tests had two types of indicators displaying the system failure: alternator failure warning light and ammeter. The other trigger events did not have system failure warning lights. The research findings show that the recognition time for the trigger event of alternator failure was much shorter (mean 11.17 seconds) than the recognition times for other trigger events (high oil pressure: mean 108.50 seconds; high load meter: mean 98.71 seconds; vacuum pump failure: mean 29.12 seconds). This result suggests the relative importance of a warning light in detecting system failures.

Inagaki, Takae, and Moray (1999) assert that a large number of flying hours do not define an expert, unless those hours include a variety of normal and abnormal experiences which lead to better judgment. In this study, participants were assigned to one of the three experience levels based on their flight education progress. Participants' total flight experience ranged from about 82 hours to 208 hours (at the beginning of this study), and each experience level had a range of about 50 to 70 hours total flight time. Study results suggest that there was no apparent significant impact of experience level on participant performance across all four areas that were monitored (adherence to a recommended solution, recognition time of an abnormal aircraft condition, appropriateness of response, and response time). This supports the notion that participants' experience levels were not greatly varied for this study.

Finally, flight simulator results for trigger event 4 (vacuum pump failure) did not demonstrate significant difference in response time between the experimental and control groups. The nature of the simulated failure could provide a possible explanation for this lack of difference between the groups. The vacuum system of an aircraft provides pneumatic power to several of the primary flight instruments. One of these instruments is the attitude indicator which provides the pilot with a primary reference for pitch and roll movements. The failure of the vacuum system is primarily indicated through a vacuum gage on the instrument panel but might also be recognized by the erratic performance of the attitude indicator. Once the vacuum pump was failed in the simulation, the vacuum pressure indication on the gage dropped immediately to zero. This was followed by the attitude indicator slowly becoming erratic, a condition that would be quickly noticed by the pilot. Thus, the participants from either the experimental group or control group who did not recognize the dropped in vacuum pressure indication might recognize the vacuum pump failure from the erratic attitude indicator display. Once they recognized the vacuum pump failure, the only possible step for the corrective action was to turn on the electrical vacuum pump switch. The lack of notable difference between the experimental and control

group responses may be attributable to the fact that more than one indicator of vacuum failure existed providing enhanced opportunity for identification of the problem.

CONCLUSIONS

This study has investigated whether safety information has a beneficial effect on aeronautical decision making for students in a collegiate flight program. Researchers monitored a group of flight students who periodically reviewed ADAM (safety information) and a group of flight students who did not. The data collected included participant responses in terms of: (a) adherence to a recommended solution, (b) recognition time of an abnormal aircraft condition, (c) appropriateness of response, and (d) response time. Research findings suggest that flight students who periodically reviewed ADAM completed more timely and effective responses to the four malfunction areas monitored during the study. Study participants who periodically reviewed ADAM also made decisions and took actions that were closer to the solutions recommended by aviation experts than students who did not have access to ADAM.

Study findings suggest that flight students who periodically reviewed safety information demonstrated an improved capacity for aeronautical decision making ability in comparison to those who did not. Although any generalization of these findings to all pilot trainee populations may be premature, they do represent an important area for further investigation. A safety information system similar to the one used during this study may not only assist in tracking of aircraft discrepancies for maintenance purposes, but also provide a valuable enhancement to pilot decision making for all flight training programs.

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